

# NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering  
Materials Laboratory Division  
Washington, D.C. 20594



May 18, 2016

## MATERIALS LABORATORY FACTUAL REPORT

Report No. 16-043

### 1. ACCIDENT

Place : Ranger, Texas  
Date : May 11, 2015  
Vehicle : Piper PA-28-161, N3024S  
NTSB No. : CEN15LA228  
Investigator : Michael Folkerts, AS-CEN

### 2. COMPONENTS EXAMINED

Remnant of #4 piston crown  
Pieces of #4 connecting rod  
Piston pin cylinder  
Pin plug fragments

### 3. DETAILS OF THE EXAMINATION

On May 11, 2015, about 2241 central daylight time, a Piper PA-28-161 airplane was substantially damaged during a forced landing near Ranger, Texas. The pilot was seriously injured and the passenger was not injured. The flight departed from Abilene Regional Airport (ABI), Abilene, Texas about 2210 and was destined for Cleburn Regional Airport (CBN), Cleburn, Texas.

While in cruise, the pilot reported that he heard "two knocks" from the engine, followed by propeller stoppage and a total loss of power. After attempting to regain engine power without success, the pilot executed a forced landing into a field, during which the left wing was damaged due to impact with a tree. The engine was a Lycoming O-320-D3G.<sup>1</sup> The airframe had undergone 10672 hours at the last inspection on May 4, 2015. The engine had undergone 9309.93 total hours, with 11.46 hours since the last inspection, and 2135 hours since the last overhaul.

Figure 1 shows the #4 piston crown from the underside, as received. The lower portions of the crown had fractured, which were submitted as extra debris. The debris, as well as much of the piston, exhibited smearing and batter consistent with post-failure impact inside the reciprocating engine. Of note on the piston crown underside were two

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<sup>1</sup> The Lycoming O-320 is a family of 92 different normally aspirated, air-cooled, four-cylinder, direct-drive engines commonly used on light aircraft. The -D3G variant has 160 hp (119 kW) at 2700 rpm, with a compression ratio 8.50:1.

thumbnail-shaped cracks, each located about an oil drain hole along the top oil groove on the piston circumference.

The two thumbnail cracks were labeled A and B for the purposes of this report. Figure 2 illustrates thumbnail crack A on the piston crown. This crack experience less damage than the other thumbnail crack (labeled B). Crack A exhibited crack arrest marks, consistent with progressive fracture. Closer examination of the crack features found that they had propagated from initiation sites along the circumferential oil groove, at or near the oil drain hole (Figure 3).

Examination of thumbnail crack A using a scanning electron microscope (SEM) revealed fatigue striations, which were not readily observable at the end of the fatigue crack (see Figure 4 and Figure 5). Figure 6 shows a closer view of one of the crack initiation sites (located at the corner of the oil drain hole). This and the opposite crack initiation sites had been obliterated by post-fracture smearing damage and batter, and could not be used to determine the cause of fatigue crack initiation. Outside of the fatigue cracks, dimple rupture, consistent with overstress fracture, was observed (Figure 7).

The chemical composition of the piston crown was inspected using energy dispersive x-ray spectroscopy (EDS) and x-ray fluorescence (XRF). The composition was consistent with a high-silicon aluminum casting alloy. A portion of the piston crown was sectioned, mounted, and polished. Figure 8 shows the typical microstructure of the part, which was consistent with a cast aluminum alloy. The hardness was inspected per ASTM E18.<sup>2</sup> The hardness of the section averaged 65 HRE. The electrical conductivity of the part was inspected per ASTM E1004.<sup>3</sup> The conductivity averaged 38.5% IACS.

Thumbnail crack B, shown in Figure 9, was the larger of the two cracks. The damage to this crack obscured many of the fracture features. As with crack A, this crack exhibited features consistent with fatigue cracking that initiated at the circumferential top oil groove on the piston. Examination of the fatigue crack initiation sites found that they had been damaged such that they did not yield any conclusive information about the crack initiation mechanism (see Figure 10).

Upon sectioning and handling fatigue crack A, the specimen fractured along the oil drain hole. This unintended laboratory fracture revealed a second fracture surface, consistent with a second progressive crack (see Figure 11 and Figure 12). When inspected using a SEM, this second crack was revealed to exhibit fatigue striations (as shown in Figure 13). Examination of the crack arrest marks and fatigue striations found that this second crack had propagated from multiple crack initiation sites along the oil drain hole and the inside surface of the piston crown. Most of these initiation sites had been damaged, consistent with post-fracture damage.

<sup>2</sup> ASTM E18 – *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

<sup>3</sup> ASTM E1004 – *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*. ASTM International, West Conshohocken, PA.

Examination of the area near fatigue crack B revealed that there was also a second crack present (see Figure 14). The features of this crack were consistent with having initiated along the oil drain hole, propagating diagonally inward towards the crown surface.

The piston pin and connecting rod from the #4 piston location were inspected to determine if this accident bore similarity to a previous engine failure in which the piston pin fractured.<sup>4</sup> The piston pin is displayed in Figure 15. The barrel of the pin exhibited some discoloration and circumferential wear, consistent with the prior position of the attached connecting rod.

However, the surface of the pin was generally smooth, containing no missing material that would have been consistent with corrosion pits, gouging, or spalling. The condition of this piston pin was inconsistent with the one that failed in the aforementioned previous investigation.

The fractured pieces of the connecting rod are illustrated in Figure 16 and Figure 17. The connecting rod fragment that was attached to the piston pin had been bent along the fracture location. The other fragment, from the connecting rod shaft, had fractured in two places and twisted. One of the shaft fragment fracture surfaces exhibited features consistent with overstress. The other fracture had been damaged by post-fracture smearing.

The fracture surface of the connecting rod fragment closest to the piston crown is highlighted in Figure 18. Most of the fracture surface exhibited a rough, tortuous texture, consistent with features typical of overstress failure. However, some of the regions on the fracture surface along the tensile portion of the bend exhibited crack arrest marks, consistent with progressive fracture. These areas are highlighted on Figure 18.

Examination using a SEM found the progressive regions to exhibit striations consistent with fatigue crack propagation (Figure 19). The fatigue striations observed were limited to small regions denoted in Figure 18. The remaining undamaged portions of the connecting rod fracture surface exhibited slanted dimple rupture, consistent with shear or multiple-direction overstress (see Figure 20).

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<sup>4</sup> NTSB investigation CHI04LA181 that occurred in Austin, TX on July 9, 2004. The NTSB determined the probable cause of the accident to be the loss of engine power due to a fatigue fracture of a piston pin that led to oil starvation.



Figure 1 – The underside of the piston crown, as received. The two fatigue cracks are highlighted at the oil drain holes (arrows) where they were located.



Figure 2 – Closer view of fatigue crack A, as labeled on Figure 1.



Figure 3 – Closer view of the oil hole from Figure 2, showing the crack initiation sites. The arrows denote crack direction.

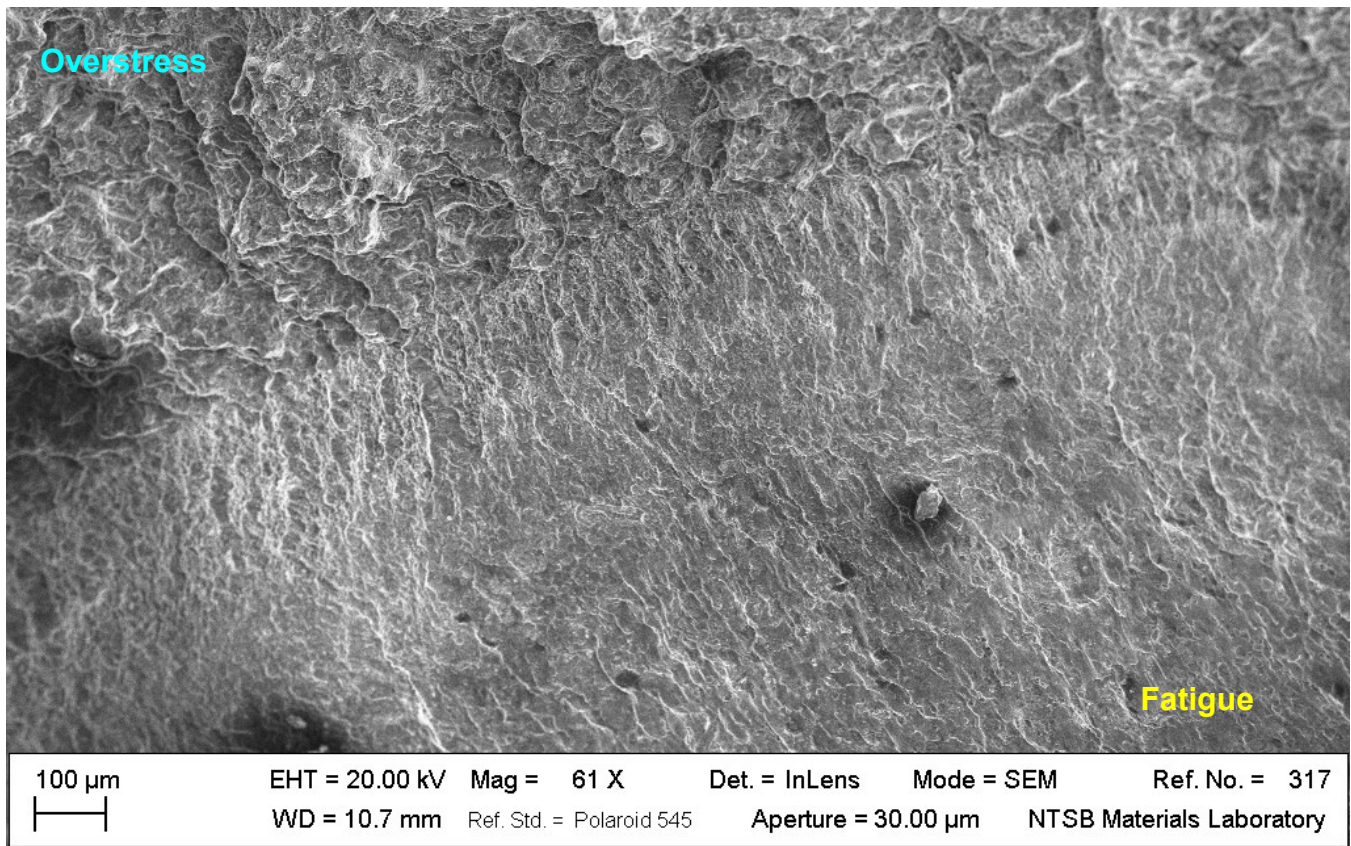


Figure 4 – Secondary electron (SE) micrograph of the end of the fatigue crack A.

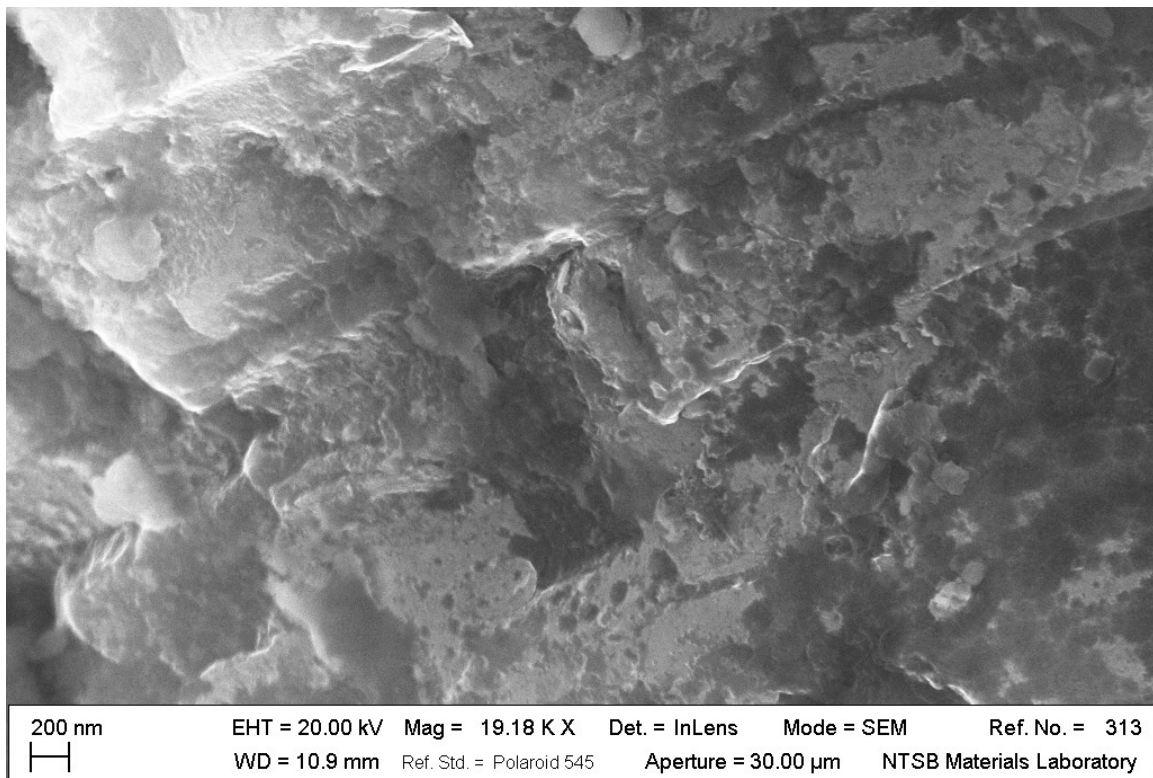


Figure 5 – SE micrograph showing a closer view of the multiple fatigue striations in fatigue crack A.

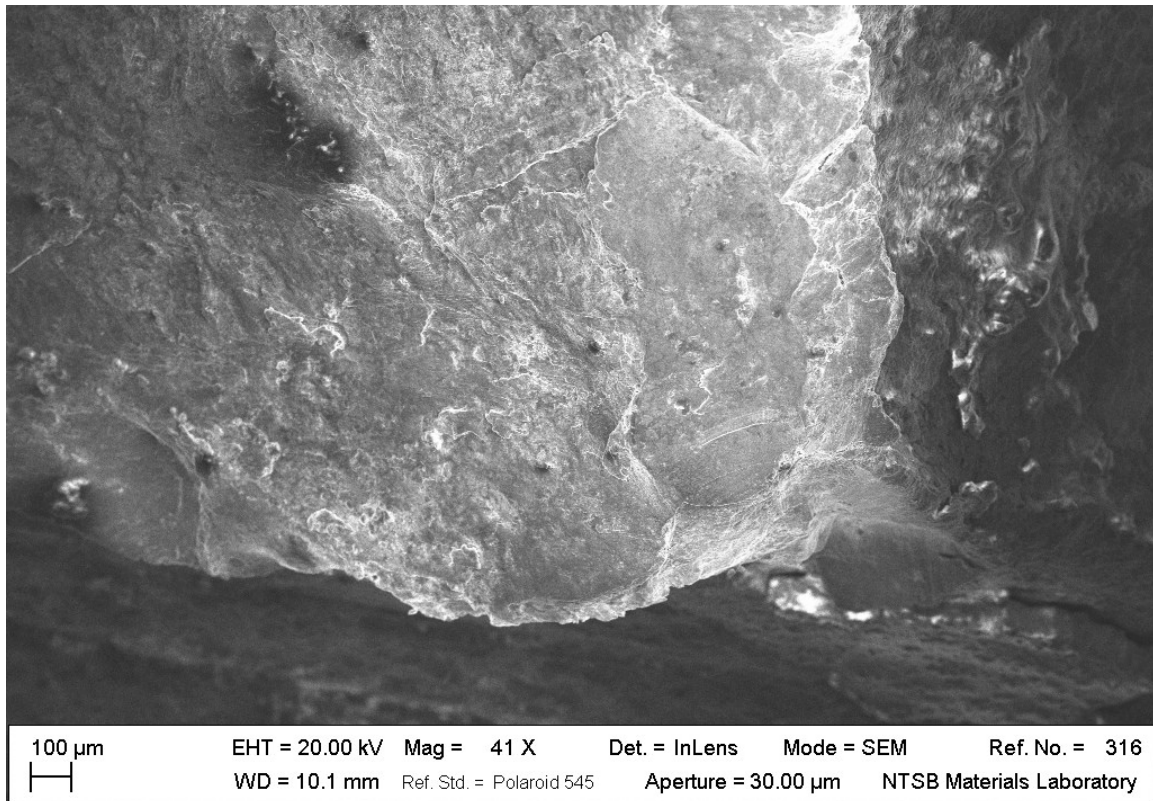


Figure 6 – SE micrograph showing the corner crack initiation of fatigue crack A at the oil drain hole.

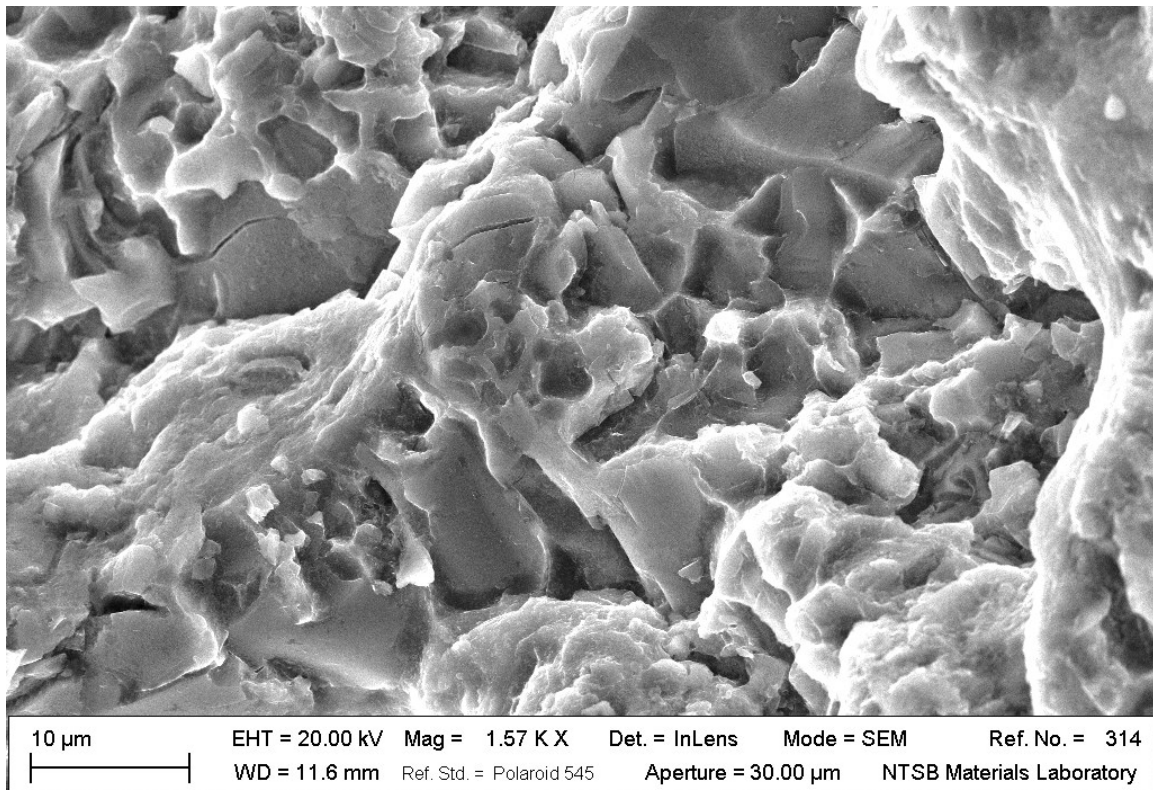


Figure 7 – SE micrograph showing dimple rupture, consistent with overstress, preceding the termination of fatigue crack A.

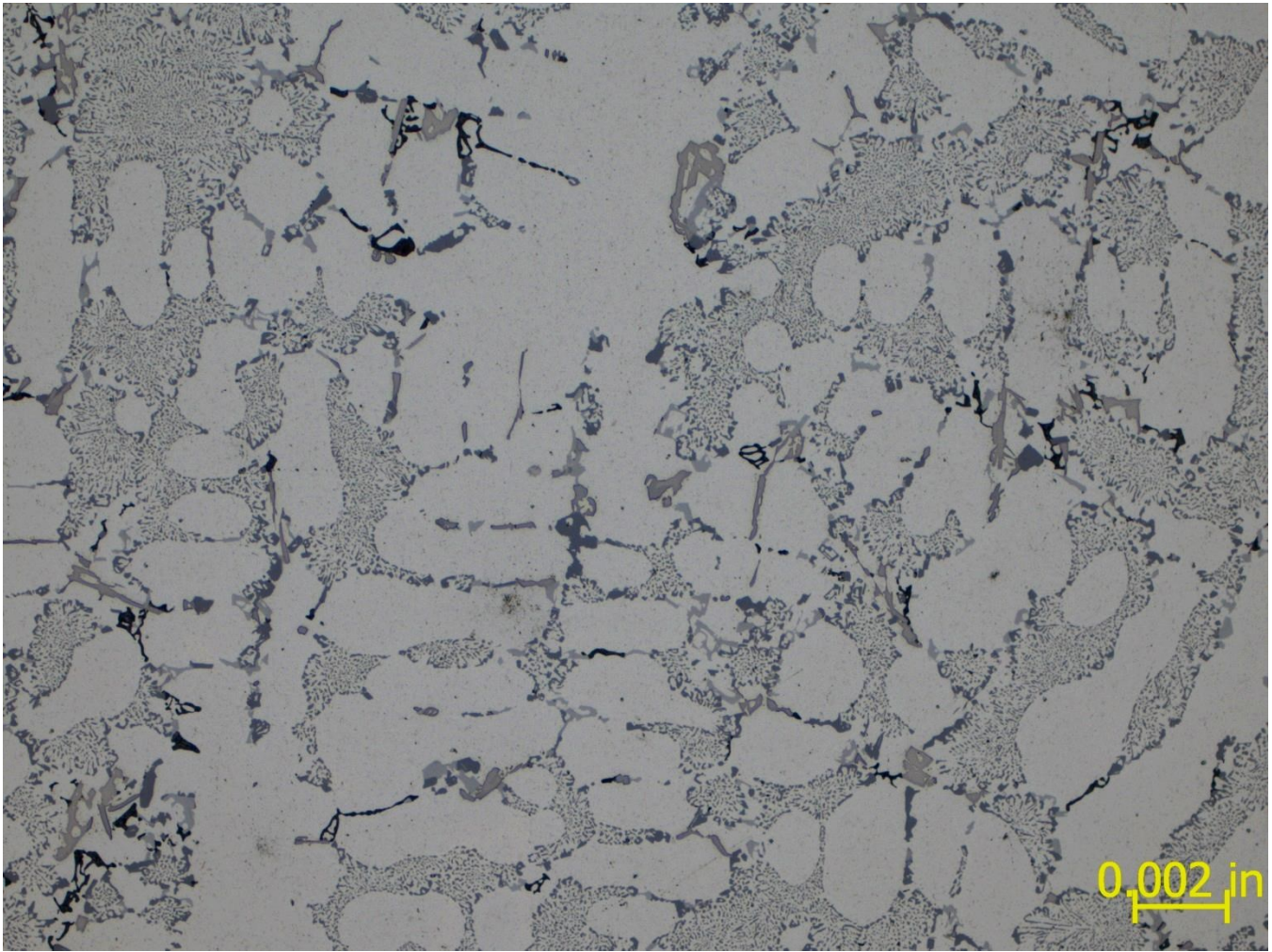


Figure 8 – Bright-field metallograph of the piston, showing a dendritic solidification microstructure with high-silicon second phases, typical of cast aluminum alloys (as-polished, ~100X).



Figure 9 – Closer view of fatigue crack B, as labeled on Figure 1.



Figure 10 – Closer view of the oil hole in Figure 9, showing one of the crack initiations sites.

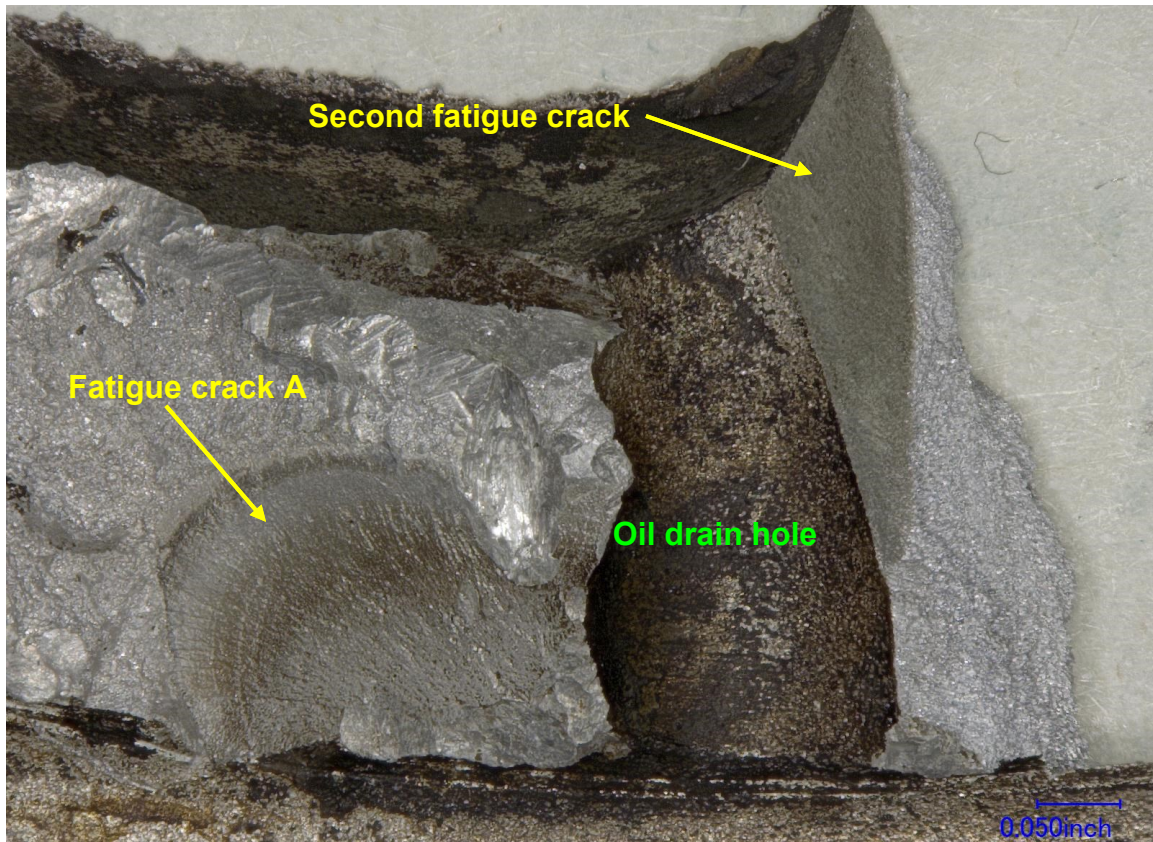


Figure 11 – Fatigue crack A, after a portion fractured from handling, revealing a second fatigue crack.

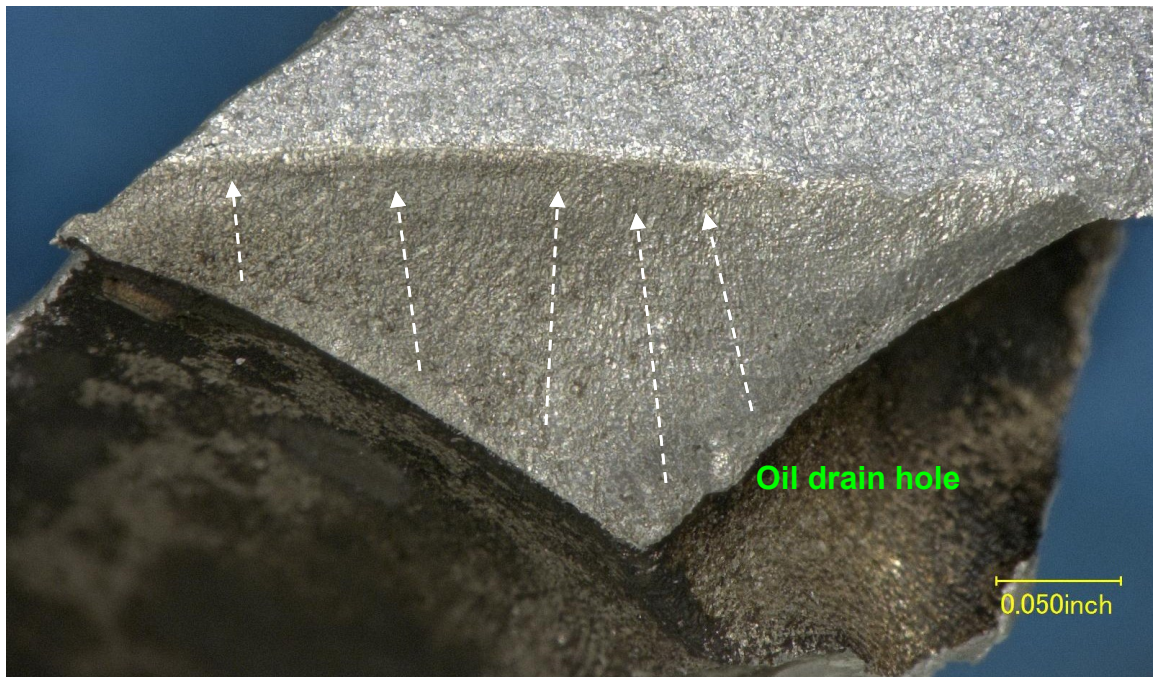


Figure 12 – Closer view of the second fatigue crack from Figure 11, showing the crack growth direction (arrows).

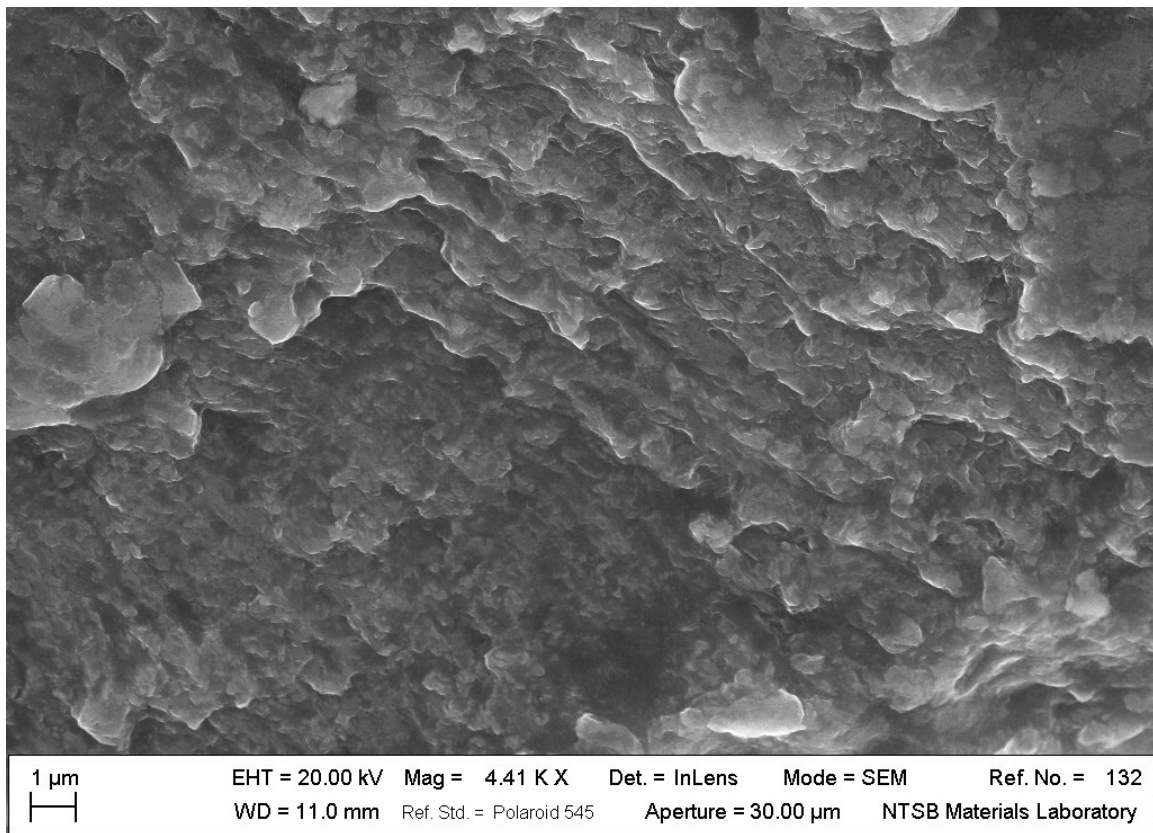


Figure 13 – SE micrograph of the 2<sup>nd</sup> fatigue crack near fatigue crack A.

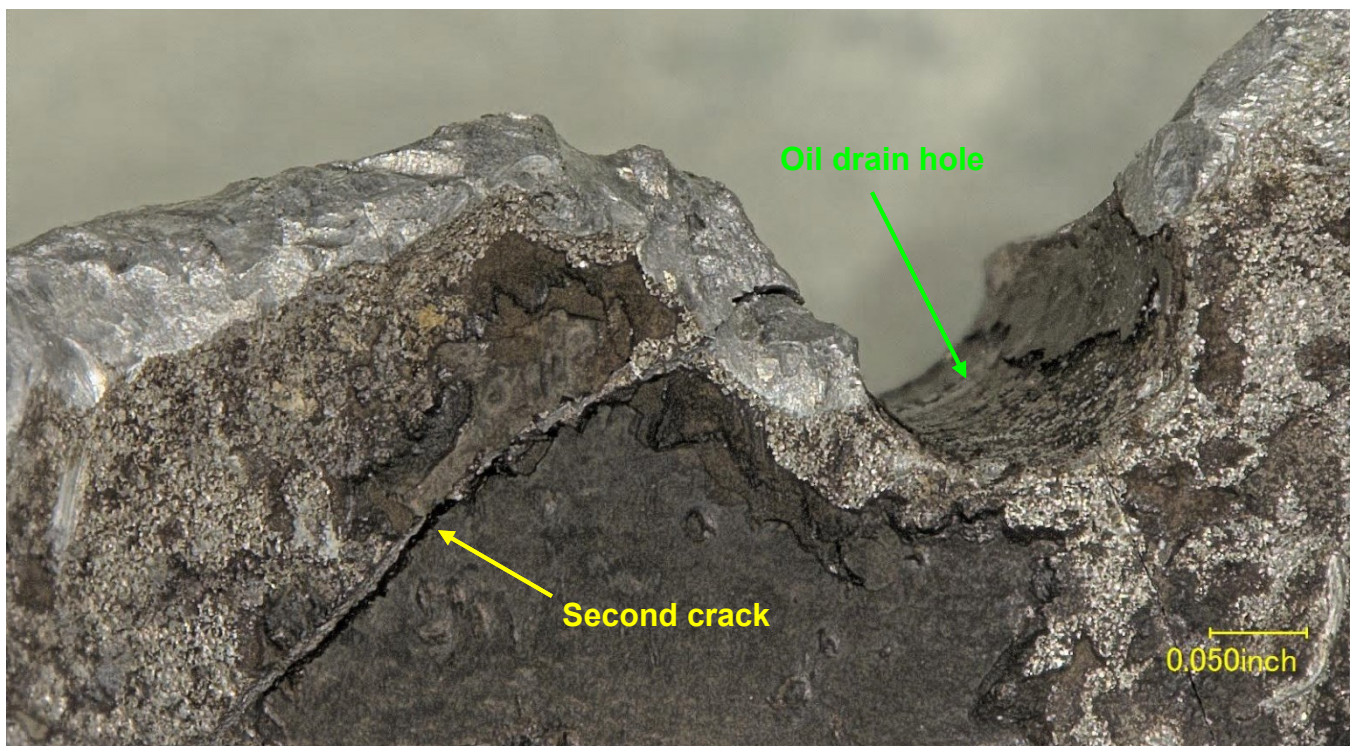


Figure 14 – The sectioned piston crown piece containing fatigue crack B (not pictured), viewed from the inside out, showing a crack propagating from the oil drain hole where fatigue crack B initiated.



Figure 15 – The piston pin, after disassembly and cleaning.



Figure 16 – The connecting rod fragment that was attached to the piston pin, after cleaning and disassembly.



Figure 17 – Fragment of the shaft from the connecting rod, as received.

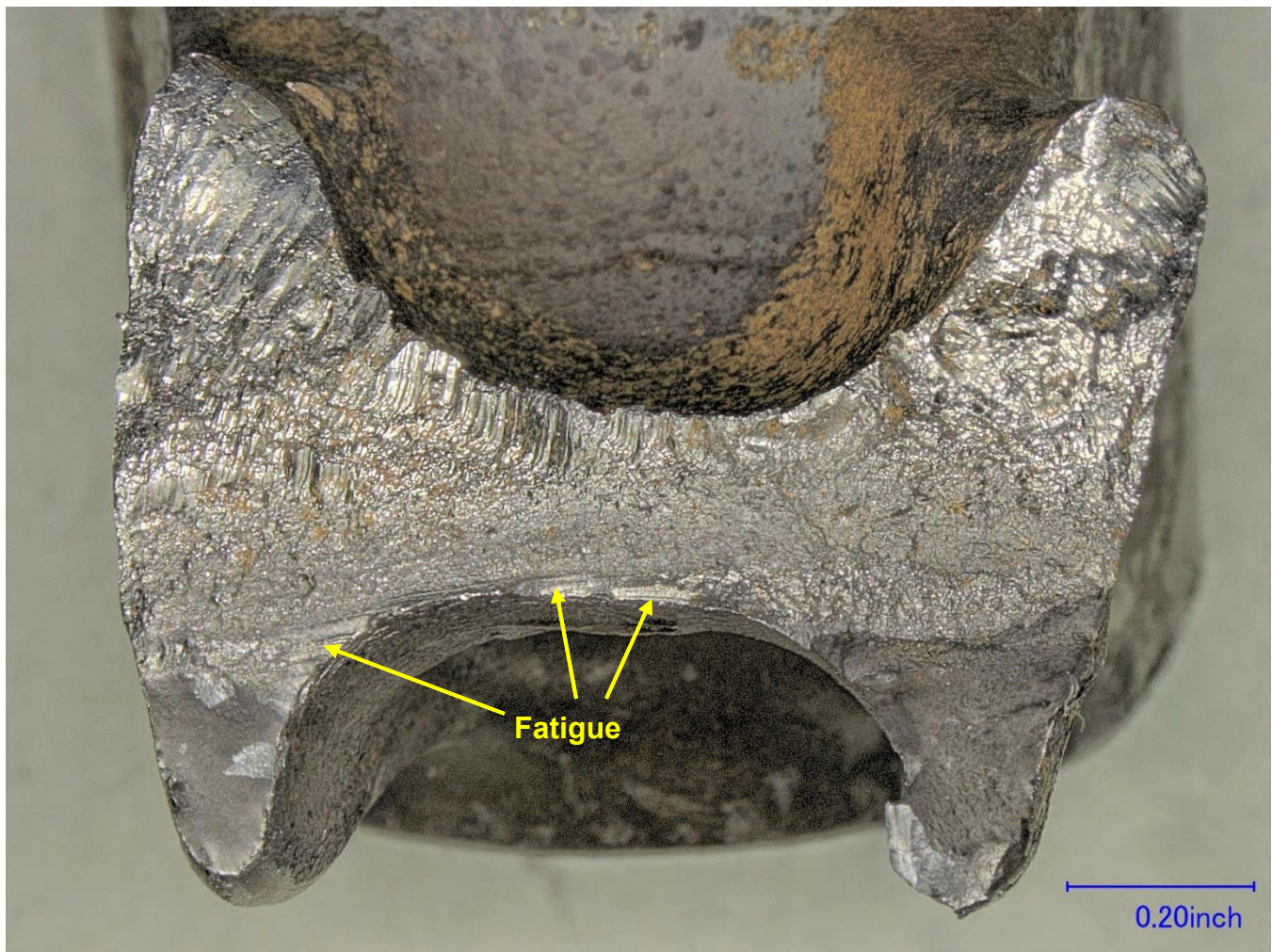


Figure 18 – Closer view of the fracture surface of the connecting rod fragment from Figure 16. The small regions of containing fatigue features (see Figure 19) on the tension side of the bending are labeled (yellow arrows).

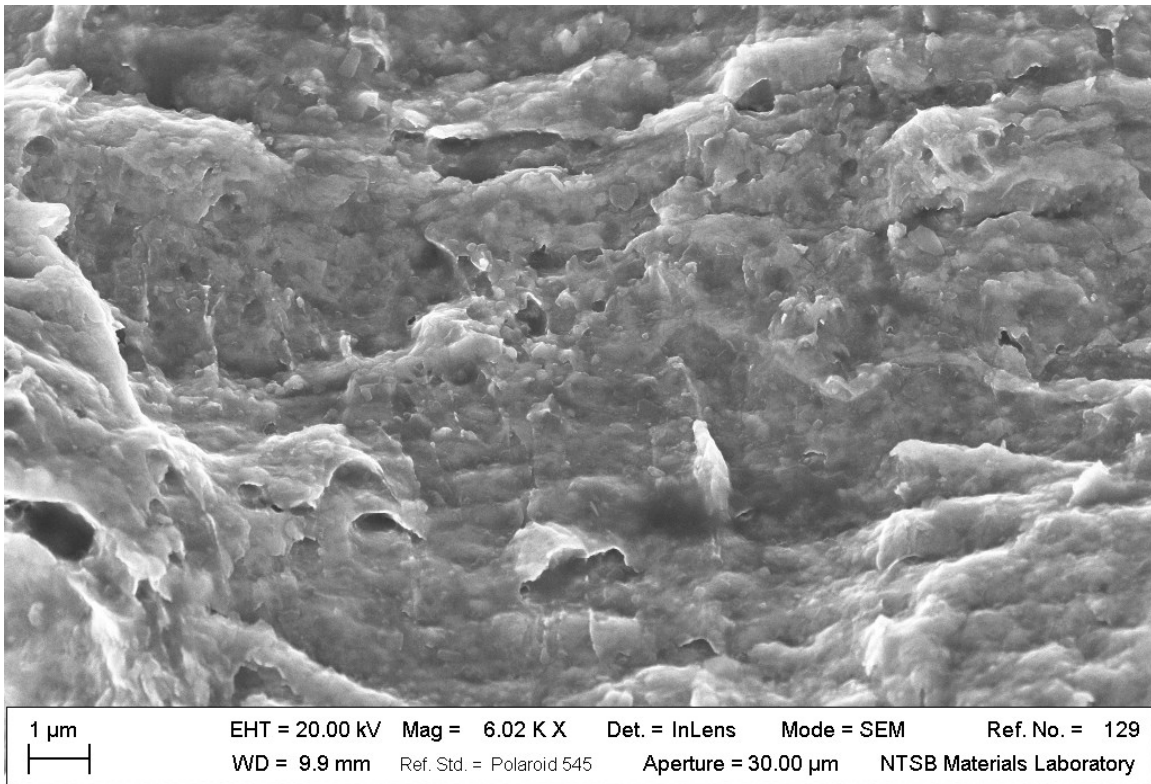


Figure 19 – SE micrograph of the fatigue regions of the connecting rod fracture surface.

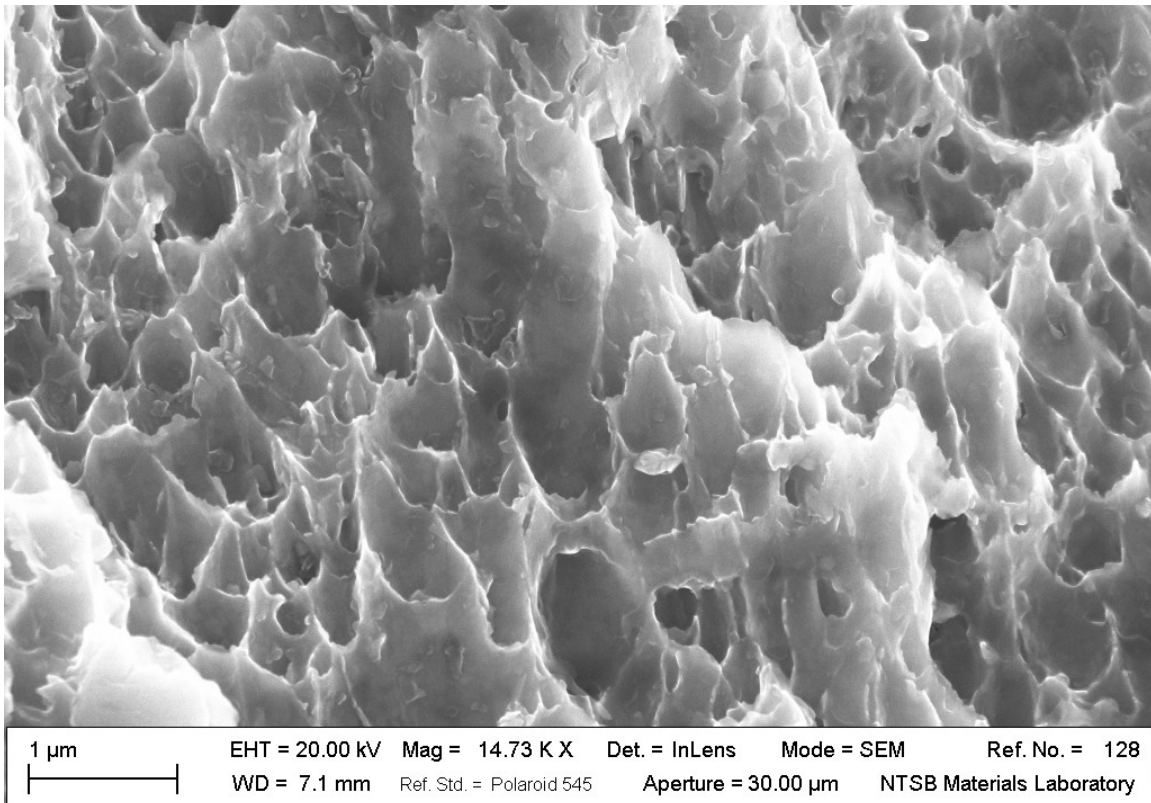


Figure 20 – SE micrograph of the overstress regions on the connecting rod fracture surface.